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TECHNIQUES OF SPACE GEOGRAPHY, WAYS OF DEVELOPING THEM AND THEIR USES IN STUDYING THE EARTH'S NATURAL RESOURCES

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ABSTRACT. At present, in connection with the development of space research and the creation of various highly sensitive instruments for recording the electro-magnetic radiation of the Earth's surface from space, the necessity has arisen of developing a new scientific discipline which we call space geography. Space geography includes the study of local, regional, zonal and planetary relationships in the composition, structure dynamics and rhythm of the geographic sphere. This is done by recording the Earth's electro-magnetic field from aircraft and interpreting images and spectra of the Earth's surface in several spectral bands for the use and preservation of natural resources.

Closely connected with space geography is the study of the Earth's sister planets. Space vehicles record the electro-magnetic fields of these cosmic bodies. Therefore, space geography techniques, besides their primary purpose, should aid in the development and testing of original methods and standards for studying other planets from various kinds of space vehicles.

The methodological advantages of space geography techniques lie in the three ways of integrating images of the Earth from space observations: territorial, factor and dynamic (Vinogradov, 1966a). /86*

a. Territorial integration involves unifying in one image vast and spatially remote elements of the geosphere in large macro- and mega-structures. Territorial integration makes it possible (by using space photos) to study vast territories simultaneously. It is possible to show features such as planetary and regional fracturing, latitudinal and altitudinal zonality,

* Numbers in the margin indicate the pagination in the original foreign text.

macro-and mega-combinations of the vegatation of physico-geographic regions and land forms, the composition of geological macrostrucutres, ring and dome-like upheavals, complex depressions of relief macroforms (eolian ridges, rifts, etc.)

b. Factor integration consists of uniting in one image all the physiognomic components of the geosphere (climasphere, hydrosphere, lithosphere, biosphere and anthroposphere), determining the relation between components in the landscape and finding latent components of the geosphere using tracers. Factor integration makes it possible to study (by space photographs) the relationship of the composition and distribution of very distant elements of the geosphere and to trace, to a considerable extent, the relation of the frequency and dimension of eolian sand ridges to geological structure; the relation of channel currents with underwater river canyons; the relation between cloud forms and distribution and the physical properties of the subsurface and relief; the relation of seacoast relief with currents and movements of deposits suspended in ocean water, etc.

c. Dynamic (and rhythmic) integration is based on a comparison of successive images of the same territory, obtained by the same recorders with various time intervals. Dynamic and rhythmic integration makes it possible, by a series of successive images, to judge the intensity, extent and frequency of natural processes, both rhythmic (diurnal, annual and seasonal) and catastrophic physico-geological. Cause-effect relationships can also be characterized between natural phenomena in distant territories: movement and development of cloud systems; glacial movement; change in the snow cover line; phenological changes in forests; origin of forest fires; movement of water masses of various origins in seas and oceans, etc. These general characterictics of space geography are typical of all space techniques of surveying natural resources. /87

Techniques of Space Geography

Depending on the method of registering geospheric data, we distinguish six basic types of space photography of the Earth: 1) visual space observation

(λ = 0.3 - 0.65 μm); 2) space photography (λ = 0.3 - 1.1 μm;) 3) spectro-photometric recording (λ = 0.3 - 3.0 μm); 4) space infra-red recording (λ = 0.01 - 3 mm); 5) space microwave recording (λ = 0.3 - 10 cm); 6) space radar (λ = 3 - 70 cm).

The different kinds of recording are not of equal value, informativeness, specialization and development. While some types of observation are already in use, others are in the ground and air testing stages.

1. Visual Space Observations

Visual observations from manned space vehicles (MSV) have been made by many astronauts, and some of their observations have been published (Shepard, 1961; Cooper, 1963; Nikolayev, Popovich, 1963; Resta, 1965, etc.).

From manned vehicles (MV) at altitudes of 200 - 300 km, astronauts have observed and distinguished objects of very small size and low color contrast. Unfortunately, the primary consideration in the observation programs has been given to locating products of civilization in the landscape. Astronauts turned their attention mainly to transportation and communication lines industrial objects, etc. However, they made a number of observations which indicate the possibility of using visual methods to study natural conditions. The astronauts observed structural features of the cloud cover; color patterns of the twilight aureole of the Earth; contacts of blue ocean waters with brown shades of channel river waters in undersea canyons; depths of the ocean floor on banks and coastal shelfs; fields with various agricultural conditions, etc. The astronauts' observations attest to the great geometric discrimination of the human eye which, as Cooper noted, increases during weightlessness.

The potentialities of visual observations from MSV are determined by a number of technical, physiological and geographical factors which have, as yet, not been well researched (Narva, Muckler, 1963; Resta, 1965).

The prospects of visual observations of the geophere from MSV indicate their very important, although secondary, role in the study of the Earth's natural resources. They can be divided into two parts: (1) specified and (2) unspecified by the program.

1) Visual observations specified by the program could be used for: /88 (1.1) preliminary identification of projected objects of photography and spectrometry; (1.2) choosing objects from a number of analogous objects, according to the best photography and spectrometry conditions (depending on cloud distribution, illumination, visibility and transparency of the atmosphere) during the flight. In this way it would be possible to compensate for specified objects of photography and spectrometry covered by clouds or by analogous objects where there was no opaque cloud cover; (1.3) conducting photography and spectrometry experiments on the same objects in various aspects to determine the reflection coefficient; during different solar altitudes, illumination and weather to determine natural photographic conditions with various films and filters in order to choose the best recorder for natural resources; (1.4) conducting experiments identifying geometric and color tests to determine vision discrimination in outer space according to different illumination, visual angle, physiological conditions, etc.

2). Visual observations of the Earth from space vehicles (SV) not specified by the program include: (2.1) observation (and also photographic and spectrometric recording) of natural objects and phenomena, the composition, structure and distribution of which cannot be explained by the astronaut-explorer in terms of scientific data known to him; (2.2) observations (and also photographic and spectrometric recording) of natural and anthropogenic processes and phenomena which have developed during the flight and information which he would not have known during preflight preparation. Such observations not specified by the program could reveal a number of short-lived phenomena; traces of rain, high tides, landslides, dammed lakes, forest fires, dust and sand storms, seismic sea waves, volcanic eruptions, earthquakes, hurricanes, etc.

2. Space Photography and Television Reconnaissance

Of all the methods of recording the electro-magnetic field of the geosphere for studying natural resources, the greatest amount of information is given by photography in the visible and near infra-red bands of the spectrum (wavelengths from 300 to 1100 nm). All images of the Earth in this spectral band, according to the method of obtaining and analyzing them, can be divided into: (1) original photographs obtained from SV or automatic stations and returned in capsules to the Earth, and (2) television images transmitted from artificial Earth satellites (AES) and received on television channels on Earth. Both methods have a number of advantages (the first -- the high discriminatory capacity of the image, the second -- the regularity of obtaining successive images of the Earth's surface) and supplement each other.

The trends of scientific development and practical application of space photography and television reconnaissance are varied and extensive. We will discuss the basic features of their use in studying individual components of the geosphere.

The most developed fields of the application of satellite reconnaisance are meteorology and atmospheric physics. There is extensive literature in both these branches. We will only mention a number of important works which characterize and generalize the basic trends of the research (Kondratyev, 1963, 1966; Kondratyev, Borisenkov, Morozkin, 1966; Kondratyev, Avastye, Fedorova, Yakushevskaya, 1967). Television reconnaissance of the Earth's cloud cover from the American "Nimbus", and "ESSA" satellites and the Soviet "Meteor" have provided global information for meteorological studies. Such reconnaissance has contributed much to science and the national economy. The /89 development of research in this field has now made necessary the automation of processing and analyzing the images obtained in this region of the spectrum.

In oceanography, interpretation of space photographs from SV and television images from AES has also given outstanding results. Great success in this field has also been reached in the study of ice cover distribution and dynamics (Taggart, 1963; Wark, Popham, 1963), the study of ocean currents (Wilkerson, 1967) and ocean surface (Moore, Pierson, 1967). A number of other studies also have interesting results, although they remain problematic: the study of ocean floor relief of coastal shelves and banks (Zaitzeff, Sherman, 1968); the movement of schools of fish in correlation with satellite data about currents and temperature conditions of the water, flourescence (Saur, 1965), etc.

In the field of land hydrology, the greatest success has been attained in studying the water distribution in the solid state. A number of new ice sheet structures "oases", isolated mountains and thermal anomalies among them, and mountain glaciers were studied by space images of Antartica, Greenland, and Central Asia (Popham, Samuelson, 1965). For the first time a sequential objective picture was obtained of the descent and formation of snow cover in valleys and mountains. This is especially valuable for places with an inadequate network of snow measuring stations (Fritz, 1963; Tarble, 1964).

Individual cases of geological interpretation, especially of original space photographs obtained from SV, have also been very successful, although they have not received as much development as in the field of hydrometeorological and oceanographic research. Interpretations of rockets and tectonic structure were made with the details of geologic maps (scale 1:500 000). New data have been obtained about the geological structure of poorly studied regions. It has been found that space photographs contain more information than geological maps of the same scale. Successful regional experiments in geological analysis were conducted in the Western Sahara (Morrison, Chown, 1965), Pakistan (Hemphill, Danilchik, 1968), Southern Arabia (Meer Mohr, 1968) and the Republich of Chad (Persora, 1968).

Geomorphologic interpretation is one of the promising trends in the use of space photographs for studying the Earth's surface. However, there are few special projects in this direction. This is related to the absence of a special geographic program of satellite reconnaissance. By means of space photographs, macro- and mezo-relief forms have been studied and traced which [illegible] successfully traced on the ground: longitudinal dunes of [illegible] 1966), [illegible] relief (Lowman, 1965), etc.

[illegible] processing of space photographs and television images of the Earth have made it possible to construct more accurate topographical maps of poorly studied regions of Antarctica (Mapping by satellite, 1966) and Peru (Mackallor, 1968).

Soil, vegetation, and agricultural land interpretations remain the least developed areas and are weakly represented in research programs, although it is evident that in view of their physiognomy the possibilities of studying them by space photographs are indisputable.

In soil science there is only one area in which space photography may be used. Space photographs could be used to calculate the moisture reserves in soils of level regions of the steppe and semi-desert zones shortly after a rain (Hope, 1966). However, the small number of experiments only indicates the inadequate scientific and programmed development in this direction. The same goes for the study of agricultural lands. /90

In [illegible] research, space photographs and television images make it possible to study macro- and mega-combinations of vegetation (Vinogradov, 1966b), to map the distribution and inspect the condition of forests (Wilson, 1967), to detect forest fires (Singer, 1962), and to trace phenological vegetation (Conover, 1965). These initial observations have already contributed promising results.

The use of space photography in biogeography is problematic, although intense research is being carried on in this direction. The ordinary observation method in this field is correlation based on the relationship between insect, fish and animal migrations and the dynamics of ecology. By analyzing the meteorological situation, the appearance of locusts can be predicted, (Sayer, 1962) and by analyzing oceanographic conditions, schools of fish (Saur, 1965), etc.

The most promising is the complex interpretation of landscape from space images based on simultaneous analysis of differing order, (zones, regions, landscape, districts) and combined identification of individual geospheric components (atmsophere, lithosphere, hydrosphere, biosphere, and anthroposphere) which are integrated into specific systems (Vinogradov, 1967, 1969).

Unlike the limited SV research programs (meteorological, oceanographic, geological, etc.) which predominated in the early states of research, the idea is now being developed of a complex program for a many-faceted study of natural resources. Such a program would make it possible, on one hand, to combine the interests of various disciplines, and consequently, to use the costly satellite information more completely for different branches of science and the national economy. This would greatly increase its efficiency. On the other hand, it would be possible to correct observations of one cycle by others, which would considerably increase its accuracy and thoroughness. Such an idea could only be completely realized by a complex orbital laboratory program with multi-discipline use of satellite information for natural resource research. It is being considered both in the USA (Badgley, Vest, 1966) and in the USSR (Vinogradov, Kondratyev, Setpanenko, 1968).

Space Spectrometer Recording

Making use of the spectral differences in radiation reflection by various natural formations in the visible, near and far bands of the spectrum and the spectral characteristics of the thermal radiation of natural surfaces, indirect methods are now being developed to solve this problem: to identify, by signals received by recorders placed in various kinds of vehicles, natural formations which are hundreds and thousands of kilometers away.

Space spectrometry is based on recording reflection spectra of solar light and the Earth surface's own radiation in wavelength bands from λ = 300 nm to the microwave region. The advantage of spectral reconnaissance lies in the fact that, by using appropriate receivers and transmitters, it can give selective optical characteristics within narrow zones of the spectrum. If necessary, it can also correct individual narrow-band spectral measurements. Thus, the selectivity of spectrometric recording makes it possible to obtain new kinds of /91 information about the Earth's surface which were not possible by ordinary photography.

Based on the nature of the receivers and information transmission, space spectrophotometry can be correspondingly divided into three spectral bands: (1) visible and near infra-red (300 - 1100 nm), (2) infra-red or thermal (1.1 - 30 μm) and (3) microwave (centimeter and decimeter radiation).

3. Remote Spectrometer Recording (Wavelengths from 0.3 - 1.1 μm)

The first space spectral measurement of reflection and radiation of Earth formations were made from the Soviet SV "Soyuz-7". At the same time, to solve the problem of space spectrophotometry, combined laboratory, ground and aircraft measurements of albedo and spectral brightness constants are very important. They are valuable to determine the theoretical possiblities of space spectrometry of the Earth's surface, as well as to determine the requirements for constructing spectrometric instruments installed in AES.

Research on spectral brightness coefficients and albedo of natural surfaces has been conducted from aircraft in the USSR and abroad for many years (see Kondratyev (ed.), 1969). However, in view of the extreme complexity of the optical characteristics of natural objects and their many variations it has been feasible to divide all natural formations into only four classes (Krinov, 1947): 1) soils and rocks, 2) vegetation, 3) snow and ice surfaces, and 4) water surfaces. In addition to these, a separate classification was made for cloud formations (Kondratyev, Mironova, Otto, 1965).

More detailed spectrometric research indicates a closer relationship between spectral brightness coefficients and albedo, on one hand, and the composition of natural objects on the other.

In aerial spectrophotometric reconnaissance, rocks are mainly differentiated in the visible spectrum by their mineral content (Romanova, 1962). An analysis of spectral brightness coefficients in the visible spectrum is so detailed that sands of different origin can be distinguished (alluvial and eluvial, Koret-Dag and Pamir-Alaiskiy, etc.).

Vegetation can be subdivided by spectral brightness coefficients according to life forms (Vinogradov, 1966b). Hydrophyte, mesophyte, xerophyte and halophyte formations are distinguished by the distribution of spectral brightness coefficients. Also differentiated are aspects which depend on phenological development and ecology (Colwell, 1967; Shay, 1967). By spectral brightness coefficients, phytopathologic reconnaissance of forests and crops can be conducted, and diseases detected before they are visible to the eye (Colwell, 1956). Although the whole spectrum is more informative, from the point of view of interpreting data from satellite measurements, reasonable results from satellite spectrometry can be found in recording the spectral brightness coefficients and albedo in two or narrower parts of the spectrum and determining the coefficient,of their relationship (K). Such coefficients are chosen for their selectivity towards one or other type of natural formation. Thus, K 850/650 clearly differentiates surfaces covered with green vegetation (K 850/650 - 4 - 15), bare soil and rock (K 850/650 = 1.2 - 3.0) and snow /92 surfaces (K 850/650 - 0.75 - 1.0) (Kondratyev, Mironova, Otto, 1965). At the same time, water surfaces and clouds (water) (K 850/650 - 0.9 - 1.0) are not well distinguished from snow cover using the mentioned K 850/650. To divide other types of natural formations, corresponding coefficients in other bands can be suggested: for example, for spectrometry of water surfaces and shallow water depths K 450/560 is recommended; for spectrometry of vegetation -- K 560/640, etc.

The use of corresponding values of spectral brightness coefficients provides the basis of the solution of one of the most difficult problems of remote recording -- the problem of distinguishing snow from clouds. An analysis of cloud and snow surface measurements shows that this case necessitates supplementary reflection data in the part of the spectrum around $\lambda = 1.65$ μm where contrasts between clouds and snow can reach 0.65 - 0.75 (Chapurskiy, 1968).

4. Spectrophotometric Thermal Recording from Space at Wavelengths from 1.5 to 30 μm.

Reflection and natural thermal radiation spectra are specific for various natural surfaces. However, the reflection spectra in the far infra-red region (3 - 30 μm) have been less well studied than in the visible and near infra-red region.

Encouraging material has been obtained in detailed study of minerals in thermal radiation spectra from 1 to 25 μm (Lyons, 1964). They indicate the possibility in principle of identifying rocks by thermal radiation spectra. Curves for the spectral distribution of radiation intensity for such minerals as quartzite, feldspar, dunite and calcite differ greatly. The basic criterion in differentiating polished minerals is the location of minimum radiation: in quartzite at $\lambda = 8.4$ and 9.2 μm; in feldspar, $\lambda = 8.6$; 9.5 and 10.0 μm; and in dunite and calcite, at $\lambda = 11.2$ and 11.4 μm, etc.

The very important factors which determine the spectral features of thermal radiation are surface roughness, particle size and physical fractures on the surface. As a rule, the amount of radiation decreases with increased surface roughness. At $\lambda = 9.0$ μm, when particle size decreases from 100 to 1 μm, the peak of the voltage curve increases from 0.62 to 0.91. At the same time, there is a decrease in the specific character of the spectral reflection curve, which can be expressed by the spectral contrast K 9/11 μm. The latter gets larger with an increase of particle size from 0 to 0.61. These data show how strongly individual features of the spectrum are "erased" in proportion to the fragmentation of the sample. It has been discovered that radiation spectrum identification of some minerals (for example, dunite and granite) is possible only when particle size exceeds 100 μm. Thermal recording from space was used to map subsurfaces, measuring the radiation in various bands from 3.5 - 30 μm from the AES "Nimbus II" and constructing charts of equivalent temperatures (Pouquet, Raschke, 1968). /93

Another promising trend in thermal recording is the study of volcanic formations, tectonically active regions and thermal zones (Friedman, Williams, 1968). As photography in bands from 3.5 - 5.5 and 8.15 μm has shown, similar phenomena are recorded in nighttime aerial reconnaissance from great heights (Fisher, 1964); McLerran, 1967). Important results have been attained in thermal probes of the atmosphere from satellites (Kondratyev, Timofeyev, 1970).

In hydrological and oceanographic research, thermal recording can be used to characterize various temperatures of water surfaces, turbidity, pollutions, phytoplankton and coastal water rvegetation (Kondratyev, Zhvalev, Ter-Markaryants, 1967; Lopik, Pressman, Ludlum, 1968). Infra-red photos, obtained from AES, in this spectral zone, can be used for ice reconnaissance (McLerran, 1967), for studying sea currents and the extent of water masses of various temperatures (Wilkerson, 1967), and for surveys of equivalent temperatures of the sea surface (Allison, Kennedy, 1967).

In studying plant cover, the thermal wavelength band (8 - 15 μm) can be used primarily to detect and determine the extent of forest fires when smoke interferes with ordinary aerial photography (Carneggie, Lauer, 1966). As more detailed studies have shown, many types of vegetation show perceptible differences in wavelength bands from 3.5 - 5.5 and 9-18 μm (Colwell, 1967).

5. Thermal Radar Recording from Space at Wavelengths from 0.3 - 10 cm.

Thermal radar reconnaissance records radio brightness temperatures and contrasts of radio brightness temperatures making it possible to evaluate energy contrasts of various geospheric components by means of recording from space.

In atmospheric research, this band can be used to study the general water vapor content of the atmosphere (Stealin, 1967; Kondratyev, 1969). With the precision of satellite measurements, the general moisture content amounts to 8% and the moisture content of clouds -- 15%.

In oceanography and hydrography the microwave band can be used to detect icebergs and evaluate ice, as reflections in this spectral zone are greater from water than from ice. Also promising is the use of thermal radar to measure the moisture content of snow (Kennedy, 1968) and to detect precipitation zones in cloud fields (Stepanenko, 1966).

Aircraft research in this spectral zone has also detected differences in land areas. Thus, territories covered with forests are 5°K cooler than unforested lands (Hyatt, 1967).

6. Radar Recording from Space

Active space radar is a promising solution to a number of recognizable problems -- for example, studies of clouds and precipitation. An analysis of a basic radar equation shows that the required emission strength and instrument sensitivity is presently adequate to provide the energy resolution necessary to detect local irregularities on the Earth's surface. Various wavelengths are suggested to identify different objects. /94

To detect clouds and precipitation from satellites with a probability not lower than 0.9, the optimum wavelength band of 2 - 3 cm is recommended (Kigler, Krawitz, 1960; Stepanenko, 1966). Radar can also be used to determine parameters of sea surface agitation (Moore, Pierson, 1967; Zubkovich, Marchenko, 1965). The principle of agitation research is based on measuring coherent and incoherent components of radio-signal reflections from the sea's surface. In aerial-borne radar at wavelengths of 3 cm, this method makes it possible to show the force of agitation, to give information about the effective slope of the waves and the existence of small irregularities on the sea surface, and to distinguish wind waves from ripples, etc.

For radar recording of ground formations, the optimum range is between 3 - 75 cm (Dellwig, Moore, 1966). The use of radar demands multifrequency and multipolarizing systems to increase the quantity and accuracy of information. This leads in turn to complex statistical signal processing to obtain information with the necessary probability.

In ice cover research, radiowave recording can be used to detect icebergs, to trace ice boundaries and to determine ice clearings and separations. It can record possible hummocky ice and fissures in old ice covered with snow (Dellwig, Moore, 1966; Loshchilov, Shkolnikov, 1965).

To study and trace a land hydrographic network it is necessary to locate second-order river systems and in some cases even third-order. In establishing correlations with topographic parameters, it becomes possible to determine the catchment basin, basin perimeter, tributary length and steepness of valley slopes (Moore, Simonett, 1967).

In geological research, by radar reconnaissance, the geological structure and composition of bedrock not established by ordinary aerial photographs can be found. The future advantages of microwave reconnaissance is its considerable depth of penetration (to 3 - 4 m) and the fact that vegetation, snow cover and clouds do not effect the identification of bedrock (Simpson, 1966; Macdonald, Brennen, 1967; Dellwig, Moore, 1966).

In the study of vegetation and agricultural lands, radar recording can determine the boundaries of fields and forests, areas and even kinds of crops and land classification: forests, meadows, shrubbery, swamps. Indications are that the presently inadequate results may be essentially improved by satellite radar (Morian, Simonett, 1967; Moore, 1967).

Scientific Trends in Developing Practical Applications of Space Geography

In a brief article, it is impossible to cover all the many ways of developing space geography. We will note three basic divisions of this research: /95
1) the study of the geosphere; 2) the development of methods and techniques of space geography; 3) the application of the results of space geography to the study of other cosmic bodies (space extrapolation).

In view of the brevity of this account, we will be limited to just the enumeration of the basic scientific and practical trends (leaving out meteorological problems).

1. The Study of the Geosphere

1.1 Meteorology and atmospheric physics (not discussed in this article).

1.2 The study of oceans and seas.

1.2.1. Observation of ice-cover distribution and ocean currents to determine the global strucutre of moisture and heat exchange.

1.2.2 Observation of sea-ice movement to determine its connection with meteorological conditions and ocean currents and with depth distribution and water mass characteristics.

1.2.3. Tracing the time of formation and discovery of ice cover and ice field drift to maintain navigation, for the fishing industry and for short-range ice predictions.

1.2.4 The study and tracking of ocean currents for the construction of detailed ocean current charts and the study of seasonal current migrations.

1.2.5 Observations on catastrophic ocean phenomena, such as underwater volcanic eruptions and seismic waves from research and operational notification.

1.2.6 Study of tidal zones to determine their dimensions, to calculate tidal energy, construct coastal defenses, for naval construction and application of tidal energy.

1.2.7 Identification of the topography and lithologic composition of underwater continental slopes to depths of 50 - 100 m to chart shallow water.

1.3 Study of land water.

1.3.1 Charting snow-cover distribution, tracking the formation and descent of snow cover, determining thawing speed and its effect on the growing season in order to forecast river drainage, to regulate reservoir levels, plan industrial and agricultural water supply, and design water communications.

1.3.2 Study of lakes, observations on the duration of lake ice, determining the dynamics of freezing and discovery of ice, study of lake-bed relief, geomorphologic and geologic characteristics of a lake basin for fish industry planning, water energy use, lake level regulation and optimal discharge of water reserves for irrigation.

1.3.3 Inventorying mountain glaciers and studying Arctic and Antarctic ice sheets, determining their areas and volumes, genetic classification, clarifying accumulation and ablation fields, geomorphologic and geologic characteristics of their attitudes in order to predict their dynamics, determine their role in the water balance, and their use as fresh water sources.

1.3.4 To determine seasonal flooding areas of surface water (floodplains, estuaries) to calculate water collections, for storing surface drainage water and water use in arid regions and planning irrigation floodplains.

1.3.5 Tracing drainage systems, determining their connection with geomorphological conditions in order to plan engineering construction, drain marshlands, and collect surface water in arid zones.

1.3.6 Hydrogeologic regionalization, tracing source distribution, /96 and finding ground water supply and discharge zones in order to study the distribution and dynamics of underground water.

1.4 Study of geomorphologic structure and topography of relief.

1.4.1 Study of the spatial correlation of large genetic relief complexes, for example glacial complexes in valleys, and particularly in nearly inaccessible mountain regions, more precise definition of boundaries and genesis for global geomorphological charting and regionalization in scales of 1:1 000 000 and better, and local charting in scales of 1:500 000 and larger.

1.4.2 Finding the relationship of large relief forms with geological composition, with geological structures, especially with fault-tectonic forms, with the composition of rocks in order to improve geological charting and mineral prospecting methods.

1.4.3 Study of erosion network diagrams showing separation, configuration and density; explaining how the erosion network is connected with various morphogenetic types of relief, with geological composition features as tracers of geomorphologic mapping in order to study erosion processes, surface water drainage and ravine networks.

1.4.4 Study of lake basins and various kinds of depressions (sink holes, caves, pseudocaves), their configuration and distribution orientation, morphology and genesis, comparative features of their development in various natural zones for geomorphological and geological-engineering research.

1.4.5 Explanation of the distribution of eolian forms, their configuration, orientation, connection with orography, with the wind regime of surrounding territories in various natural zones in order to evaluate plant reclamation, sand defense and transportation construction.

1.4.6 Detection of various kinds of lineaments (erosion and tectonic terraces), tracing their course in large areas, determining their relationship with geological structure and paleogeography.

1.4.7 Study of seacoast and lake-region structure, study of delta regions, revealing sea and lake terraces of various ages for paleogeographic analysis of the territory and geologic-engineering research.

1.4.8 Obtaining convergent photography and developing photogrammetric methods of space photography of the Earth in order to determine elevations in compiling topographic maps of poorly-studied and difficult-to-reach territories.

1.5 The study of geological structures and mineral prospecting.

1.5.1 Study of planetary faulting for determining the general development of the Earth's crust and megatectonic structure, locating zones of possible mineral deposits.

1.5.2 Study of lineaments, detection of new ones, more precise definition of known fault-type tectonic irregularities, especially in hard-to-reach and poorly-studied territories and also where they are concealed by loose Quaternary deposits for compiling middle and fine-scale tectonic and geologic maps.

1.5.3 Study of folded structural forms, finding broken dome-shaped structures, tracing ring-like megastructures and geological mapping, scanning promising areas for oil and gas deposits. Finding the interrelationship of folded and faulted geological structures in geological research to determine promising mineral deposits zones.

1.5.4 Tracing individual geological series, stacks and rocks of /97 marker stratigraphic beds for middle and fine-scale geological mapping in scales of 1:1 000 000, 1:500 000 and larger.

1.5.5 Study of analogous geological structures in large regions for the construction of correlated geological diagrams, comparison of remote territories which are similar in certain features (geomorphological, magnetic) for the construction of a world geologic map (scale 1:1 000 000).

1.5.6 Use of infra-red recorders for detecting heat anomalies along tectonic contact zones and volcanically active areas to predict earthquakes, volcanic eruptions and for finding minerals having long wave radiation.

1.5.7 The use of ultraviolet recorders for finding mineral deposits, having high shortwave reflection.

1.5.8 Evaluation of the engineering and military-engineering conditions of a location: penetrability, enclosability, camouflage, and presence of building materials for military-engineering maps and predictions.

1.6 Study of soil cover

1.6.1 Observations on the distribution of soil types and the most important indices of soils in order to construct specific soil maps on a scale of 1:1 000 000 and finer and for soil-geographic regionalization.

1.6.2 Territorial generalization of soil differences for finding soil types in determining specific mapping and regionalization units.

1.6.3 Determining territories subject to soil erosion, both water and wind, for calculating eroded soil areas, revision of old maps, inspection of erosion intensity and plant reclamation reconnaissance of the Earth.

1.6.4 Observation of the extent of salinated soils, calculation of relative proportions of salinated soils in massifs, tracing the dynamics of salinization and the water regime of soils and geomorphological and geological soil salinization for planning reclamation systems.

1.6.5 Observations of soil-surface moisture, its distribution in large territories, tracing diurnal and annual dynamics, calculating moisture reserves in the upper soil layers for agrometeorological predictions and evaluation of agricultural water supply.

1.7 Study of vegetation cover.

1.7.1 Study of the natural distribution of vegetation and determining the size of territorial mapping units for constructing specific middle and fine-scale geobotanic maps.

1.7.2 Finding vegetation zones and boundary structures between zones in order to construct global diagrams of the vegetation cover.

1.7.3 Fine-scale regionalization and mapping of vegetation in order to construct an objective and specific unified map of world vegetation (scale 1:1 000 000).

1.7.4 Study of seasonal changes in vegetation in large areas as the basis for more detailed mapping of seasonal plant mass changes and also for finding yearly anomalies in plant development, of advance or delay, for planning pasturing, redistribution forage supplies and predicting crop yield.

1.7.5 Study of the distribution of the vegetative biomass in large areas in order to caculate pasture productivity and hay-producing plants, especially short lasting varieties in deserts, to calculate timber reserves in forest plantings and to plan efficient use of plant resources.

1.7.6 Detection of fires in forests and steppes for rapid information about their origin.

1.7.7 Entomological inspection of forests, detection of sources and extent of some pests and diseases in order to develop effective means of fighting them.

1.7.8 Inspection of forest resources, plant conditions and especially tracing the dynamics of felling timber and catastrophic plant reduction to control and conserve nature.

1.8 Study of the animal world.

1.8.1 Finding breeding sources and migration routes of insects that are harmful to plants (locust, silkworms) based on appropriate indices in order to take quick and effective measurement to protect forests and agriculture from pests.

1.8.2 Search for and detection of large types of ground and water fauna, calculation of reserves and tracing migration for correct location of bases for processing food from the sea.

1.8.3 Forecasting annual migration of fauna by indirect detection as well as directly -- depending on the duration and depth of the snow cover -- in coastal rivers and reservoirs in order to plan fish yield and reproduction.

1.8.4 Predicting fish migration by accompanying oceanographic and meteorological readings of currents and air mass movements in order to find fishing areas.

1.8.5 Study of biocomplexes to find the relationship of the animal and plant world with the environment for its protection and reproduction.

1.9 Study of agricultural lands.

1.9.1 Photography and visual observations of the distribution of arable lands and determination of yearly changes in its area in order to calculate land-use dynamics.

1.9.2 Tracking agricultural areas to determine their composition in arable lands and the dynamics of crop and rotation systems.

1.9.3 Inspection of the agricultural area conditions, altitude, isolation, ripening, disease effect, recovery, etc. in order to forecast yield of basic grain crops.

1.9.4 Observations of agricultural regions in various spectral regions to find areas subject to diseases.

1.10 Study of industrial and urban landscape.

1.10.1 Study of reservoir zones polluted by waste liquids from urban, chemical, petroleum and wood processing sources in order to determine their extent and to project measures for fighting water pollution.

1.10.2 Finding air zones polluted by the smoke from chemical and metallurgical plants and zones of plant poisoning.

1.10.3 Determining zones of damage to primary landscape structure by construction and finding the negative results of these changes in time to take measures to fight them.

1.10.4. Determining the structure of populated areas, study of their dynamics and forecasting their development for planning construction and population location.

1.10.5 Influence of construction on the mobility of sand, its eolian /99
transport and sand drifts for projection of sand defense measures.

1.10.6 Influence of construction on drainage of surface water, change of river bed migration conditions -- for forecasting underground water conditions.

1.11 Complex(landscape) research.

1.11.1 Finding natural territorial complexes ranging from different kinds of localities to regions and sectors of land for mapping and regionalization in various scales (1:100 000 - 1:50 000 000). Each of these natural complexes is characterized by specific, more or less uniform, climate, geological composition, relief, vegetation and soils. This is considered in planning complex development of a territory and all-around use of natural resources.

1.11.2 Determining the interrelation between various elements of the geosphere: between meteorological phenomena and relief, between current directions and ice cover, between geological structure and distribution of snow cover, etc., for the creation of all-around interconnected land use programs.

1.11.3 Determining combined dynamics of various landscape components in order to find cause-effect relations between them.

2. Development of Methods and Techniques of Space Geography

Along with the problems of studying certain features of the geosphere, in space geography there are also methodological problems of determining technical and natural conditions of observation, photography and spectrometry of the Earth from outer space.

2.1 Determining technical photography conditions.

2.1.1 Study of spectral brightness coefficients of natural formations and light scattering index in order to choose the best spectral bands for surveying natural objects with recorders of various spectral senstivity.

2.1.2 Spectrozonal photography of the Earth using various films with various optical filters in order to choose the best film-filter combination for surveying ground objects.

2.1.3 Reconnaissance in various scales from various altitudes with various ground resolutions for studying geometric and optical generalization in transferring from larger to superfine space scales. This is for choosing and recommending necessary scales for surveying specific groups of objects and finding a basic set of scales for obtaining information of adequate detail and at the same time of adequate size.

2.1.4 Surveys in the largest possible scales to determine maximum scale and potential limits for the most detailed information.

2.2 Determining natural reconnaissance conditions.

2.2.1 Study of optical properties of the atmosphere, such as the optical spectral transmitting function, affecting photographic and spectroscopic reproduction of geospheric elements by receivers in MV.

2.2.2 Conducting theoretical and empirical research on the influence of time of day, type of weather and season of the survey on the reproduction of geospheric details, their stability and choice of optimum time for surveying objects in various geographic zones and landscapes.

2.2.3 Reconnaissance of various aspects of natural objects for studying the possibilities of obtaining surface features of the Earth and choosing optimal parameters of azimuth and optical axis inclination in photographing the surfaces of various morphological structures. /100

The Value of Space Geography for Space Planetary Research

Space research of the Earth simulates the study of possible space analogues of several Earth objects. Therefore, many studies emphasize that space photography of the Earth will be the source of material for interpretation of planets (Lowman, 1966; Vinogradov 1966a, etc). Similar space extrapolation of ground and air spectrometric and photographic methods and criteria has developed in a number of directions. In studying the eveness of the surface of Mars, it was established that its surface was analogous in texture to cold, elevated mountain desert areas of the Earth (Pamir and Jungar) (Tikhov, 1949). American studies also find a physical analogy in analyzing spectra of Mars and the Earth (Gates, Keegan, Weidner, 1966). In the "canals" of Mars, some geo areographs (Suslov, 1962) see an analogy with fault-tectonic lines on Earth, whose images in aerial photographs correspond to bands of increased moisture along faults in the gray-brown background of the desert. Fine-scale aerial photographs of huge Earth craters are being studied for interpretation of photographs of lunar craters (Genoweth, 1962). In studying the eveness of the Moon's surface analogously with the texture of various Earth surfaces, conclusions were drawn about the character of the lunar surface (Sitinskaya, 1964, 1969) which were later confirmed.

Recently, research of key ground regions has become still more specialized. In a special program using orbital spacecraft for studying natural resources, a section was set up to study key regions on Earth as possible lunar analogues (Badgley, Chids, Fisher, 1965). A large portion of these studies has been devoted to the influence of optical and geometric generalization on transformation of images. Data about the spectral composition of infra-red reflection can also be used to judge the mineralogical composition of the surface of planetary rocks (Lyon, 1964).

Conclusion

In conclusion, we must note the complex and multifaceted problem of surveying the Earth from space, both by observation and data processing methods. By observation methods we mean visual, photographic, spectrophotometric and thermal, radiothermal and radar surveys. Their uses are still more varied : in atmospheric physics and meteorology, oceanography and land hydrology, geology and geomorphology, soil science and lithography, in crop and agricultural landscape studies. The complexity of installing various units in space vehicles for sensing the electromagnetic field of the Earth in various wavelengths creates well-known technical difficulties in constructing an orbital laboratory to study natural resources. Such complex units are absolutely necessary for a more or less successful study of natural resources because: 1) mutual control of various recorders considerably increases the accuracy of each separate type of information obtained about the surface of the Earth; 2) the addition of various recording receivers, mounted on space vehicles, increases the quantity of information much more than the number of recorders is increased; 3) an increased number of receivers also increases the volume of information more than the number of receiving channels is increased; 4) in view of the fact that receivers placed in space vehicles record reflection and radiation simultaneously from various components of the geosphere (atmosphere, lithosphere, hydrosphere, biosphere and anthroposphere) and various territories, space measurements of the Earth's electromagnetic field should have multidiscipline uses in natural resource research.

In connection with the above, it can be concluded that one of the leading problems in the next 5 - 10 years in the space geography field must be the development and realization of a comprehensive orbital space station for studying natural resources with systems that record the electromagnetic field of the Earth in various spectral bands. Such a station as a large, manned, long-functioning laboratory was discussed by the president of the USSR Academy of Sciences, academician M. V. Keldysh, at a press conference on November 4, 1969.

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